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Energetics, yield, water use and economics of rice (*Oryza sativa*)-based cropping system in flood-prone situation of eastern Uttar Pradesh

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ABSTRACT

A field experiment was conducted during 1996–99 at Ghaghraghat, Bahraich, to study the energy requirement, yield, water use and economics of 7 rice (*Oryza sativa* L.)-based cropping systems in flood-prone areas. Rice–lentil (*Lens culinaris* Medikus)–maize (*Zea mays* L.) + fodder cowpea [*Vigna unguiculata* (L.) Walp.] system gave significantly highest rice-equivalent yield (95.82 q/ha), water-use efficiency (83.83 kg grain/ha-cm), net profit (Rs 30,249/ha), benefit : cost ratio (3.35) and production efficiency (Rs 75.02/day/ha) compared with rest of cropping sequences. Rice–wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–maize + cowpea (F) sequence ranked second with regards to net profit, rice equivalent, water-use efficiency and production efficiency. Rice–pea (*Pisum sativum* L., s.l)– maize + cowpea (F) system gave the highest energy input (38.02 MJ x 10^3/ha) while the highest energy output (907.75 MJ x 10^3/ha) and energy-use efficiency (29.52) were obtained in rice–Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson]–maize+ cowpea (F) sequence. Land-utilization efficiency was the maximum (91.78%) in rice–linseed (*Linum usitatissimum* L.)–maize + cowpea (F), followed by rice–lentil–maize + cowpea (F) system (90.41%).

Key words : Rice-based cropping systems, Energetics, Flood-prone situation, Economics

Rice is the main staple food grain and grown extensively during wet season under rainfed lowland situation of eastern Uttar Pradesh. Lowlands near the river are flooded and rice crop is submerged 2–3 times during the wet season. Intensive cropping system is gaining popularity with increasing irrigation facilities in flood-prone area. Introduction of pulses and oilseed in the system is more beneficial than pure cropping of cereal after cereal (Umarani *et al.*, 1992). Intensive agriculture requires larger inputs of energy and water. Irrigation water and fertilizer are costly and scarce, and thus

their availability in future is expected to get reduced.

Similarly, with increase in the cost of commercial input energy and decline in fuel reserves there is a need to work out cropping system with higher energy output. Total energy output will be an acceptable dominator for assessing the performance of a cropping system. Though energetics approach is well recognized in the recent past, elaborative studies are not yet available to represent site-specific situation. Hence attempt was made to find out economically viable and higher energy out-put crop sequences based on rice crop for flood-prone areas.

MATERIALS AND METHODS

The field experiment was conducted during 1996–99 at Ghagraghat, Bahraich. The experiment comprised 7 cropping sequences with a single crop of 'Barh Avarodhi' rice during the rainy season and 7 crops, viz. 'PL 406' lentil, 'HUW 234' wheat, 'Varuna' Indian mustard, 'local' coriander (*Coriandrum sativum* L.), 'Rachna' pea, 'Tipakia' maize and 'HFC 42-1' cowpea in summer season.

The experiment was conducted in randomized block design with 3 replications. All crops were raised adopting the standard package of practices. The experimental soil was clay loam with pH 8.1, and organic carbon content (0.41%), available N, P and K 252, 14 and 132 kg/ha respectively. Fertilizer was applied @ 60 kg N + 30 kg P_2O_5 + 30 kg K_2O/ha for rice; 20 kg N + 40 kg/ha P_2O_5 for pea, lentil and cowpea; 120 kg N + 50 kg P_2O_5 + 40 kg K_2O/ha for wheat; 80 kg N + 40 kg P_2O_5 + 30 kg K_2O/ha for Indian mustard; 60 kg N + 30 kg P_2O_5 + 60 kg K_2O/ha for coriander; 80 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha for sunflower; 100 kg N + 50 kg P_2O_5 and 40 kg K_2O/ha for maize; and 30 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha for linseed. Energy input and output were calculated using the energy equivalents (Mittal *et al.*, 1985). Water-use efficiency was worked out in terms of yield (kg grain/ha-cm) of water expense including effective rains during the crop season. The intensification of time was measured by calculating values of land-use efficiency taking the crop duration in individual cropping sequence dividing by 365 days, and production efficiency was calculated by taking total production of crop in a sequence (Tomer and Tiwari, 1990). Comparison among cropping sequence was done by converting the yield of all the crops into rice equivalent, calculated on current price basis.

RESULT AND DISCUSSION

Rice-equivalent yield

The rice–lentil–maize + cowpea (F) sequence gave the highest rice-equivalent yield, followed by rice–wheat–maize + cowpea (F) (Table 1). This might be owing to inclusion of high-value crop like lentil and wheat in both the sequences. The lowest rice-equivalent yield was obtained in rice–sunflower–maize + cowpea (F) which was mainly due to lower yield of sunflower. However, rice-equivalent yield of rice–Indian mustard–maize + cowpea (F) and rice–linseed–maize + cowpea (F) were statistically comparable with each other.

Table 1. Yield, rice equivalent, water use and water-use efficiency of various cropping sequences in flood-prone area (average data of 3 years)

Cropping sequence	Yield (tonnes/ha)			Rice equivalent (q/ha)	Water use (cm)	Water-use efficiency (kg/ha)
	Rainy season	Winter	*Zaid*			
Rice–lentil–maize+cowpea (F)	2.65 (3.86)	1.29 (1.25)	15.0	95.82	114.3	83.83
Rice–linseed–maize+cowpea (F)	2.30 (3.72)	0.66 (0.63)	12.5	61.65	120.1	51.33
Rice–wheat–maize+cowpea (F)	2.59 (3.77)	2.65 (3.74)	13.0	91.98	148.7	61.85
Rice–Indian mustard–maize+cowpea (F)	2.42 (3.8)	0.68 (0.65)	11.7	59.22	132.4	44.72
Rice–coriander–maize+cowpea (F)	2.50 (3.92)	0.20 (0.18)	12.2	59.80	103.2	57.94
Rice–pea–maize+cowpea (F)	2.46 (3.88)	0.65 (0.59)	12.83	68.69	118.3	58.06
Rice–sunflower–maize+cowpea (F)	2.35 (3.78)	0.50 (0.38)	13.50	58.38	135.2	43.18
CD (P=0.05)				4.97	3.5	6.19

Figures in parentheses are straw or stover yield of respective crop
Grain (Rs/q): Rice, 450; lentil, 1,700; wheat, 650; linseed, 1,450; Indian mustard, 1,200; pea, 1,800; sunflower, 1,500; coriander, 4,000
Straw (Rs/q): Rice, 70; lentil, 45; wheat, 125; linseed, 35; Indian mustard, 40; pea, 50; sunflower, 40; coriander, 20; maize + cowpea fodder, 40

Water-use efficiency

Different cropping systems consumed varied quantities of irrigation water (Table 1). Total water use was significantly highest in rice–wheat–maize + cowpea (F), followed by rice–sunflower–maize + cowpea (F) sequence. The highest water expense under rice–wheat–maize + cowpea (F) cropping system was mainly due to substantially high water requirement of wheat crop (Table 1). Significantly lower water use among the different cropping sequences was recorded in rice–coriander –maize + cowpea (F) system. The water-use efficiency was significantly highest in rice–lentil–maize + cowpea (F), followed by rice–wheat–maize + cowpea (F). The lowest water-use efficiency was recorded in rice–sunflower–maize + cowpea (F) cropping sequence. Similarly, legume showed included sequence the higher water-use efficiency as reported by Parihar *et al.* (1990).

Land use and production efficiency

Rice–linseed–maize + cowpea (F) sequence showed the highest land-use efficiency, followed by rice–lentil –maize + cowpea (F), rice–Indian mustard–maize + cowpea (F), rice–wheat–maize + cowpea (F) and rice–sunflower–maize + cowpea (F). However, production efficiency was significantly highest in rice–lentil–maize + cowpea (F), followed by rice–wheat–maize + cowpea (F), and the lowest in rice–Indian mustard–maize + cowpea (F) sequence. The highest production efficiency with rice–lentil–maize + cowpea (F) sequence was mainly owing to higher net income and comparatively lower total duration than rest of cropping sequences (Table 2).

Energetics

The total energy input in various cropping sequences ranged from 30.75 to 38.02 MJ $\times 10^3$/ha (Table 3). Significantly highest total energy input was recorded by rice–pea–maize + cowpea (F) sequence, followed by rice–sunflower–maize + cowpea (F). In general, fertilizer accounted for single highest share of energy input ranging from 26.47 to 44.81% of total energy input in different cropping sequences, followed by irrigation and human labour. The energy input through mechanical power and seeds was of lower magnitude (Table 3). The highest energy output was remarkably higher in rice–Indian mustard–maize + cowpea (F) sequence. The total energy input was significantly highest in rice–pea–maize + cowpea (F), resulting the lowest energy-use efficiency. However, energy-use efficiency was significantly highest with rice–Indian mustard–maize + cowpea (F), followed by rice–wheat–maize + cowpea (F). The lowest energy input was recorded in rice–Indian mustard–maize + cowpea (F) sequence (Table 3).

Rice–wheat–maize + cowpea (F) sequence was found next best regarding energy output and energy input. However, output : input ratio was the maximum in rice–Indian mustard–maize + cowpea (F) and the lowest in rice–pea–maize + cowpea (F) (Table 3).

Economics

Maximum total cost was involved in rice–wheat–maize + cowpea (F) sequence, followed by rice–Indian mustard–maize +

Table 2. Economics, land-utilization efficiency and production efficiency as affected by various crop sequences in flood-prone area (average data of 3 years)

Cropping sequence	Total cost (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Benefit : cost ratio	Land-use efficiency (%)	Production effciency
Rice–lentil–maize+cowpea (F)	12,870	43,119	30,249	3.35	90.41	75.02
Rice–linseed–maize+cowpea (F)	12,300	27,743	15,442	2.26	91.78	46.09
Rice–wheat–maize+cowpea (F)	17,252	41,390	24,139	2.39	89.04	70.70
Rice–Indian mustard–maize+cowpea (F)	14,612	26,649	12,037	1.82	89.31	36.70
Rice–coriander–maize+cowpea (F)	11,400	27,910	15,510	2.44	85.47	49.71
Rice–pea–maize+cowpea (F)	13,271	30,910	17,640	2.32	89.04	54.27
Rice–sunflower–maize+cowpea (F)	12,234	26,271	14,037	2.14	86.02	44.40
CD (P=0.05)					NS	3.12

Table 3. Total energy (MJ x 10^3/ha) input, output and output : input ratio of rice-based cropping systems in flood-prone area (average data of 3 years)

Cropping sequence	Input energy					Total energy input	Total energy output	Output : input ratio
	Human labour	Mechanical power	Seed	Chemical fertilizer	Irrigation			
Rice–lentil–maize+cowpea (F)	5.65	0.35	1.25	14.70	12.50	34.45	770.5	22.36
Rice–linseed–maize+cowpea (F)	7.53	0.32	1.00	13.15	10.95	32.95	671.3	20.37
Rice–wheat–maize+cowpea (F)	6.95	0.46	1.95	16.45	17.85	36.71	870.0	23.69
Rice–Indian mustard–maize+cowpea (F)	5.10	0.45	1.85	11.40	11.25	30.05	907.8	29.52
Rice–coriander–maize+cowpea (F)	7.75	0.34	0.40	9.00	16.50	33.99	757.6	22.28
Rice–pea–maize+cowpea (F)	6.50	0.42	1.70	15.70	13.10	38.02	665.7	17.50
Rice–sunflower–maize+cowpea (F)	7.20	0.50	1.75	14.95	12.75	37.15	767.0	20.65
CD (P=0.05)	0.45	0.07	0.12	2.07	1.41	2.18	44.3	1.54

Source : Energy equivalent of various input and output were taken from Binnings, A.S., Pathak, B.B. and Poneser, B.S. 1983. The energy audit of crop production system. *Report*, Punjab Agricultural University, Ludhiana

cowpea (F). The lowest cost was incurred in rice–coriander–maize + cowpea (F) because of lower irrigation and fertilizer requirement. Rice–Indian mustard–maize + cowpea (F), rice–sunflower–maize + cowpea (F), rice–linseed–maize + cowpea (F) and rice–coriander–maize + cowpea (F), accrued more or less similar gross income. However, rice–linseed–maize + cowpea (F) and rice–coriander–maize + cowpea (F) sequences gave more or less similar net income (Table 2). The lowest income was recorded in rice–Indian mustard–maize + cowpea (F) and rice–sunflower–maize + cowpea (F) because of lower yields of both crop. Lower net returns from Indian mustard and sunflower included in crop rotation was also recorded by Singh *et al.* (1997).

The rice–lentil–maize + cowpea (F) showed the highest net income and benefit : cost ratio mainly owing to the lower cost of cultivation and higher value of lentil seed as compared with the other cropping sequences (Table 3). Rao and Willey (1980) reported that multiple cropping system with legumes offer special advantage to farmers and reduces the probability of low income.

It can be concluded that rice–lentil–maize + cowpea (F), and rice–wheat–maize + cowpea (F) cropping system were found promising in flood-prone area of eastern Uttar Pradesh.

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